PERIPHERAL STIMULI AND STEREOACUITY FOR NAVY DIVERS WORKING UNDER WATER

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SUMMARY PAGE

THE PROBLEM

To determine whether or not stereoacuity for Navy divers working under water is improved by the introduction of stimuli in the periphery of the diver's field of view.

FINDINGS

Acuity is improved only when the peripheral stimuli are approximately at the same distance from the diver as the target. When these stimuli are much closer to him than is the target, his acuity is degraded. This phenomenon seems to become more marked as the turbidity of the water increases.

APPLICATION

In attempting to judge the relative distance of objects under water, the precision of the diver's judgements will be greater if there are no visible objects near the diver in his peripheral field of view. The possibilities of improving stereoacuity under water with a face-mask whose edges cannot be seen or by a face-mask which puts peripheral stimuli at optical infinity are raised.

ADMINISTRATIVE INFORMATION

This investigation was conducted as a part of the Bureau of Medicine and Surgery Work Unit M4306.03-2050DXC5, Evaluation of Sensory Aids and Training Procedures on Navy Divers' Visual Efficiency. The present report is No. 3 on that Work Unit. It was approved for publication on 25 Feb. 1970 and designated as Submarine Medical Research Laboratory Report No. 654.

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ABSTRACT

A variety of experiments were carried out in an attempt to improve stereoacuity for Navy divers working under water by providing additional peripheral visual stimulation. Acuity is most improved when the peripheral stimuli are at the same distance from the observer as the target. As the peripheral stimuli are moved closer to the observer than the target, their beneficial effects are decreased and beyond a certain point their presence degrades acuity. This effect seems to be made worse by increasing turbidity of the water, which decreases the contrast of the distant target relative to that of the nearby peripheral stimuli.

PERIPHERAL STIMULI AND STEREOACUITY UNDER WATER

INTRODUCTION

Stereoacuity suffers a marked deterioration under water.[1] This occurs even in the clearest water when the targets appear to be as clearly visible as they are in air.[2] There are several lines of evidence which suggest that a major cause of this deterioration is the lack of peripheral visual stimulation in an underwater environment. It has been shown to be much more difficult to detect a target in a completely empty visual field.[3] Stereoacuity has been shown to be poor in observers suffering from a restricted visual field resulting from retinitis pigmentosa,[4] and it has also been shown to progressively worsen as peripheral stimuli are screened from view.[5]

It seems reasonable to assume, then, that the introduction of stimuli into the periphery of the visual field should improve these visual processes. Indeed, Whiteside and Gronow[6] have reported that superimposing a reticule on the target-area reduces the size of the target needed for detection by half, and Brown[7] has found slight improvements in the effectiveness of a reticule when its size was increased.

This report gives the results of several experiments carried out in the summers of 1968-1970 investigating the extent to which stereoacuity under water is improved by the presence of peripheral stimuli.

APPARATUS AND GENERAL PROCEDURE

Stereo thresholds were measured with a 3-rod Howard-Dolman apparatus. The three vertical rods stood in a box with a 40x50 cm, dark gray front in the center of which was a 13x36 cm window. The two outer rods were fixed in position in a line parallel to the front of the box. The middle rod was movable. The rods were 1.58 cm thick, positioned at 7.6 cm intervals, painted flat black, and seen against a white background.

Except for the first pilot study, this apparatus was set up in a round above-ground swimming pool 6 m in diameter and 1.2 m high. A round window, 20 cm in diameter, was cut into the side of the pool 76 cm from the ground, at the same level as the window of the Howard-Dolman apparatus when it was in the pool.

In the experiments to follow, the observers sometimes viewed the target through the porthole and at other times were actually in the water. In both cases, the observers wore a face-mask. When submerged, they were seated in the water with the back of the head held against the side of the pool while breathing through a snorkel.

In either case, the procedure was the same. The fixed rods of the Howard-Dolman apparatus were always 3.05 m (10 ft) from the observer, at this distance the face of the apparatus subtended 7.6 x 9.5° and the window subtended 2.4x 6.6°. Thresholds were measured with the method of constant stimuli. The middle rod was set at various positions, and at each setting, the observer was forced to judge either closer or farther than the outside rods. A frequency-of-seeing curve was drawn on cumulative probability paper and the setting at which the middle rod was judged to be farther on 50 per cent of the trials was taken as the equidistance setting. The standard deviations of the thresholds could be read directly from the graph.

The results are given in terms of variability which is more commonly used than localization error,[8] presumably because it is a more sensitive indicator and not subject to the systematic shifts which occur in localization error with changes in viewing conditions.[9]

EXPERIMENT I

The first experiment to test whether or not stereoacuity is improved by the introduction of limited peripheral cues into a restricted visual environment was carried out in air.

Stereoacuity was measured under three viewing conditions: (1) Unrestricted-Observer was permitted a full view of the laboratory. (2) "Ganzfeld"--an attempt was made to produce a featureless field of view around the test-apparatus by having the observer look through a small circular aperture in a white hemisphere which afforded him a view only of a white screen with a rectangular window, through which the rods of the Howard-Dolman were visible (see Fig. 1). (3) Stimuli on screen--viewing conditions were identical to the "ganzfeld" condition except that two large photographs taken from a magazine were hung as far to the side as possible on the screen, one on each side of the window.

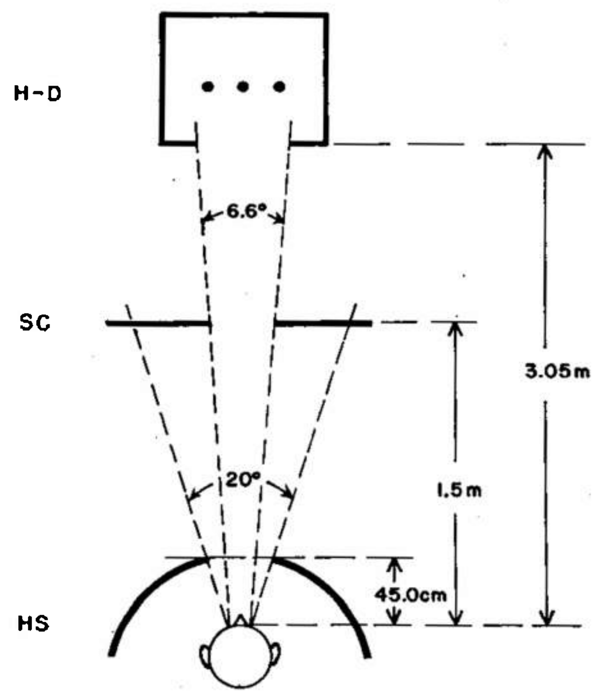

Fig. 1. Diagram of the testing arrangement, showing the observer's head positioned in the hemisphere (HS) and looking through the aperture in the screen (SC) at the Howard-Dolman apparatus (HD).

The field of view through the circular aperture subtended about 20° visual angle. The rectangular opening revealed the three black rods against a flat white background illuminated to about one foot-lambert. Lamps to either side of the screen were adjusted to match its brightness to that of the Howard-Dolman background, and another light above the observer was adjusted to match the interior of the hemisphere to the screen. With all the lights so adjusted, it was possible to discern the outlines of the apertures, but they were extremely unobtrusive (particularly when attention was centered on the rods).

The distance of the screen was set at 1.5 m simply because that was the greatest distance at which the largest sheet of cardboard available could be set without its edges becoming visible. At a greater distance, two sheets would have been necessary, and it was feared that the seam would provide an unwanted cue.

Five staff members (the first five in Table I) and five sailors served as observers. The three conditions were given in a different random order during one session to each observer. A short rest period intervened between conditions while the screens and lights were adjusted.

Table I shows that restricting the field of view degraded the precision of the equidistance setting for every observer except AR (whose thresholds remained unchanged during the experiment). When the two photographs were added to the restricted field, precision improved for all but two of the other nine observers. These changes are highly significant, according to a Friedman[10] two-way analysis of variance by ranks ($X_r^2 = 10.55$, df= 2, $p < .01$), but of course much of the variance is attributable to the great improvement in precision when the field of view is unrestricted, as reported previously.[5]

Of primary importance is the comparison between only the two restricted viewing conditions. The difference between these is significant ($p < .025$, Wilcoxon, one-tailed), clearly showing that the introduction of a limited number of peripheral stimuli into a highly restricted visual field can improve foveal stereoacuity. The remaining experiments to be reported on were carried out in the water.

EXPERIMENT II

The first experiment in the water tested the effect on stereoacuity of the placement of one or two thin, black, vertical bars in the observer's field of view. The bars were 1.27 cm in diameter and about 75 cm high. They were positioned about 60 cm in front of the observer's frontal plane and as far in the periphery as possible while still permitting them to be seen by each eye individually. Owing to the restrictions

Table I. Precision of stereoacuity
(η_σ in seconds of arc)

Observer	Unrestricted Field of View	"Ganzfeld"	Stimuli on Screen
AM	14.3	50.1	35.8
CC	3.6	7.2	5.4
TM	10.7	21.5	9.7
AR	5.7	5.7	5.7
BR	7.2	9.0	2.9
DJ	7.2	9.0	12.5
DK	4.7	17.9	14.3
EL	3.6	12.5	3.6
EA	2.8	14.3	15.4
AG	1.8	5.4	2.5
Mean	6.2	15.3	10.8

on visibility imposed by the standard face mask, this is about 20-25° away from the line of sight.

Stereoacuity was tested for each observer in the presence of both bars, with only one bar (randomly placed on one side or the other), and with no bar. The three conditions were presented in counterbalanced order, with a brief rest period between them.

First, six observers--staff members of the laboratory--were tested looking through the porthole with clear water; the rear of the pool clearly visible. Table II shows that the presence of the bars had virtually no effect on the precision of the judgments. There was certainly no general improvement; if anything, the trend was toward some slight degradation.

Next, on the assumption that the visibility of the back of the pool provided peripheral cues which were as effective as those of the bars, the experiment was repeated with six new observers--also laboratory staff members--using highly turbid water. The apparatus

Table II. Precision of stereoacuity (η_σ in seconds of arc) in the presence of zero, one, or two vertical bars in the periphery measured in clear water.

Observer	No Bar	One Bar	Two Bars
RS	7.5	7.8	7.8
RG	4.6	5.7	3.6
MH	2.4	7.8	5.7
SD	6.4	4.2	4.2
JK	10.7	7.1	10.7
LZ	2.4	6.4	3.6
Mean	5.7	6.5	6.0

now stood at virtually the limit of visibility, thus enhancing the contrast of the bars relative to the rods of the test-apparatus and eliminating all other peripheral cues in the water. Again the presence of the bars failed to improve the precision of the judgments. Table III shows that, on the contrary, the degradation of acuity was somewhat more marked than in the first set of results but was statistically insignificant according to the Friedman two-way analysis of variance by ranks.[10] In passing, the enormous increase in variability for all conditions resulting from the increased turbidity may be noted.

One final test was carried out on three Navy divers submerged in the pool, rather than looking through the porthole. Again, the presence of the bars did not improve acuity. The thresholds taken in the water, however, were much more variable than those obtained through the porthole because of such difficulties as discomfort from the cold, fogging of the face mask, and perhaps their lack of experience as subjects in psychophysical experiments.

EXPERIMENT III

It appeared likely that the negative results in the first experiment could be attributed to the fact that two slender bars simply did not constitute enough peripheral stimulation. The next attempts therefore aimed at providing more complex peripheral cues.

Table III. Precision of stereoacuity (η_σ in seconds of arc) in the presence of zero, one, or two vertical bars in the periphery measured in highly turbid water.

Observer	No Bar	One Bar	Two Bars
DW	16.1	33.6	46.5
TS	46.5	21.5	39.4
FD	14.3	14.3	23.3
HM	24.7	53.7	17.9
CC	23.3	19.7	32.2
LC	87.0	138.2	92.0
Mean	35.3	47.5	41.9

First, a coarse mesh was suspended about 60 cm in front of the observer, perpendicular to his line of sight to the apparatus. The mesh covered the entire field of view but was so coarse that it did not occlude any part of the test apparatus. The stereoacuity of six staff members was tested with and without the mesh; half observed first without the mesh and the others observed first with the mesh. Table IV shows that the presence of the mesh also produced a decrement in the precision of the stereo judgments for every observer. The mean difference was statistically significant ($p < .05$, Wilcoxon, two-tailed).

Next, an attempt was made to set up relatively complex cues without, however, impinging on the center of the field, as did the mesh. An easel and a bullseye target painted on a piece of sheet metal was substituted for the original bars. The easel was a tripod about 75 cm high with a 15x20 rectangle at the top. The target consisted of a series of concentric black circles (outside diameter 25 cm) painted on a 45x55 cm white background. The easel was set up on one side (different sides for different observers) in place of one of the rods, and the target was on the other side. The target was set up at about a 45° angle so as to form the hypotenuse of a right triangle with the observer's frontal plane and his line of sight. The target was positioned so that the circles were as far in the periphery as possible while still visible to both eyes. This typically put the far edge of the background around 100 cm away from the observer.

Table IV. Precision of stereoacuity (η_σ in seconds of arc) with and without a coarse mesh.

Observer	No Mesh	Mesh
AR	28.6	32.2
CC	13.2	35.8
FD	8.2	9.7
BR	16.1	35.8
TS	22.2	25.8
HP	30.4	30.6
Mean	19.8	28.3

Nine men who were either Navy divers or students in the Navy SCUBA class served as observers in the water. All were tested with both easel and target in place; six were tested with only the easel set up, and three were tested with only the target in position; and all were tested with no peripheral cues. The various conditions were presented in counterbalanced order.

The results for these submerged observers were again highly variable, probably due primarily to fogging of the mask. Nevertheless, the results in Table V seem to suggest that the target tended to improve stereoacuity, whereas the easel tended to degrade it. Although no differences are significant, it can be seen that when only the easel was set up, the acuity of only one of the six observers improved, and the acuity of three of the six declined quite markedly. When only the target was in place, the

Table V. Precision of stereoacuity (η_σ in seconds of arc) with and without the presence of complex peripheral stimuli, measured for observers immersed in the water.

Observer	No Peripheral Stimuli	Bullseye Target	Easel	Bullseye and Easel
KO	1.8	3.6		1.4
PR	2.9	2.1		3.6
PA	26.8	10.7		12.5
AD	14.3		14.3	16.1
OZ	41.2		32.2	12.5
UR	10.7		17.9	5.4
BR	7.2		32.2	10.7
BO	44.8		48.3	17.9
KE	5.4		9.0	20.4

acuity of two of the three observers improved. With both stimuli set up, the reverse was true; that is, the acuity of four of the six observers improved relative to their acuity with only the easel in place, whereas the acuity of two out of three observers declined compared to that when only the target was in place.

Following this, an attempt was made to improve acuity in the moderately turbid water by filling the pool with a large assortment of objects, leaving, of course, a clear line of sight to the apparatus. Six staff members were tested through the porthole. The presence of a large number of clearly visible objects throughout the field of view resulted in a marked improvement in acuity (Table VI). Only one of the six observers failed to show improvement, although this was enough to prevent the difference from being statistically significant.

EXPERIMENT IV

In examing all the results at this point, it now seemed that the essential

Table VI. Precision of stereoacuity (η_σ in seconds of arc) with test-apparatus alone in pool or surrounded by other objects.

Observer*	No Other Stimuli	With Other Stimuli
JK	17.2	6.1
AR	5.7	3.2
PS	11.5	10.7
HM	10.0	9.3
DW	37.6	17.9
JR	21.5	25.1
Mean	17.2	12.0

* The first 3 Ss were tested first with no other stimuli; the last 3 Ss were tested first with other stimuli present.

difference between the conditions that tended to degrade acuity and those that tended to improve it appeared to be their position in depth relative to the test-apparatus. Specifically, it seemed that peripheral stimuli near the observer degraded acuity, while stimuli closer to the apparatus improved it. The mesh, which constituted an extensive set of stimuli which was close to the observer at all points, significantly degraded acuity. The large assortment of objects, many of which were around the apparatus, improved it for nearly everyone. The easel also tended to degrade acuity somewhat because it was also close to the observer. The bulls-eye tended to improve acuity because it receded from the observer; although its near edge was as close as the mesh and easel had been, its far edge was half the distance to the test-apparatus. Similarly, the photographs in air were half the distance to the apparatus.

To test this hypothesis, the bars were once again used as peripheral stimuli. Six staff members observed through the porthole using clear water. They were tested either without the bars present, or with both bars set up 1.22, 1.83, and 2.44 meters from the observer and as far in the periphery as possible. The various conditions were presented in counterbalanced order and the results are given in Table VII. Whereas the presence of the bars at 0.6 m in the previous experiments had produced no improvement in acuity, their presence at the various distances in this experiment did result in improved mean acuity. Moreover, the improvement increased as the distance of the bars from the observer approached that of the test apparatus. The changes shown in Table VII were statistically significant according to the Friedman two-way analysis of variance by ranks (X^2= 9.8, df=3; $p<.02$).

These results were confirmed in another experiment in which large stimuli were substituted for the bars and the observers were in the water. An arrow, whose shaft measured about 4x60 cm, was painted on each of four pieces of sheet metal measuring 30x60 cm. Each "arrow" was clamped to a vertical rod like the ones used in the previous experiments. The four arrows could be positioned in pairs so as to form a

Table VII. Precision of stereoacuity (η_σ in seconds of arc) with target alone in water or in the presence of two peripheral vertical bars at various distances from the observer.

Observer	No Bars	Bars at 1.2 m	Bars at 1.8 m	Bars at 2.4 m
JK	17.9	9.7	7.5	5.4
AR	8.2	3.6	9.7	5.7
DW	8.6	6.1	2.1	3.9
TS	6.4	6.1	5.7	5.7
FD	7.5	3.6	3.6	1.8
RG	4.7	6.1	4.3	2.9
Mean	8.9	5.9	5.5	4.2

visual alley converging on the test-apparatus. Relatively small gaps between the pieces of metal sufficed to bring the near edge of the two closest arrows to the edge of the binocular visual field at a distance of about 1.5 m from the observer.

Two staff members and 16 sailors, none of whom had participated in these experiments, served as observers. Their acuity was measured without these arrows in place, with all four arrows in position, and with only the two closest arrows in place, thus leaving a gap between the arrows and the test-apparatus. These conditions were presented in counterbalanced order. The results are given in Table VIII.

Acuity was improved only slightly by the presence of the two closest arrows, but much improved by the presence of all four arrows. These results were also significant, according to the Friedman test ($X^2 = 8.8$, df = 2, $p < .02$).

DISCUSSION

These experiments were undertaken to test the hypothesis that it is the lack of peripheral stimulation which degrades stereoacuity under water and that the introduction of such stimuli will enhance it.

The results clearly show that peripheral cues in the water affect stereoacuity, and a most important variable

Table VIII. Precision of stereoacuity (η_σ in seconds of arc) with and without the presence of "arrow signs" measured for observers immersed in the water.

Observer	No Signs	Two Signs	Four Signs
AM	28.6	21.5	14.3
FB	19.7	25.1	19.7
BW	34.7	37.6	32.2
RR	*	62.6	43.0
TP	23.3	78.8	35.8
MM	*	98.4	35.8
AD	7.2	26.8	23.3
RW	53.7	*	75.2
MK	32.2	34.0	21.5
JD	37.6	62.6	43.0
CS	30.4	32.2	30.4
RF	150.4	*	50.1
JH	64.4	21.5	46.5
DR	30.4	34.0	25.1
GM	46.5	25.1	32.2
RS	32.2	19.7	19.7
GS	28.6	14.3	14.3
MB	71.6	21.5	28.6
Mean	47.4	46.7	32.8
Mdn	33.4	33.1	31.3

* Could not be measured due to limitations of apparatus. In computing the mean, the largest value obtained was used.

is their position relative to the target. When the cues are much closer to the observer than the target, they degrade acuity still further than is the case when there are no cues at all. This phenomenon appears to be somewhat enhanced as the turbidity of the water increases, for then the closer peripheral stimuli are of much greater contrast than the more distant target and may exert an even stronger deleterious effect. As the peripheral cues approach the plane of the target, however, they do improve stereoacuity.

There have been a number of attempts to improve the ability of pilots to detect other aircraft in an empty sky by giving them peripheral stimuli, such as reticules etched on the canopy. It is clear why such attempts have met with so little success: the stimuli on the canopy are not at the same optical distance as the targets to be detected and apparently interfere with target-detection. Improvements in target-detection have apparently been found only when the peripheral stimuli were optically adjusted to appear at the same distance as the targets, as, for example, in Whiteside and Gronow's study.[6]

An investigation just completed by Hennessy and Leibowitz[12] answers the question as to which visual processes are affected by conditions such as those in the present experiment and provides a clear explanation for the present results. They have shown that accommodation is significantly affected when an observer views a target through an aperture. The magnitude of accommodation is related to both the distance of the target and the distance of the aperture. That is, as the distance of the aperture changes while the target distance remains constant, the state of accommodation changes and reflects a compromise between the two distances.

In the present experiment, then, stereoacuity is presumably degraded by the presence of the peripheral stimuli because accommodation is altered in an attempt to strike a balance between the two sets of stimuli in the visual field, rather than remaining accommodated for the foveal target of primary interest.

These results lead to the conclusion that the improvement of stereoacuity in divers by the provision of peripheral stimuli is not a simple task. A diver will not improve his acuity by setting up additional stimuli around himself, but will be more likely to degrade it. It is necessary to provide stimuli which are displaced in apparent distance by roughly the same amount as the target. It is conceivable that this could be done optically through a special lens in the face-mask which would make peripheral stimuli appear to be at optical infinity. Whether such masks are feasible, however, is another question and what they would do to other visual processes is not known. Another more easily investigated possibility is that stereoacuity will be improved through the use of "wide-field" face-masks whose rims curve around the head and are therefore not visible. The advertised utility of these masks is simply the increased visual field, but it seems highly likely that an additional benefit will be an improvement in acuity because there are no longer the clear outlines of the mask encompassing the visual field. Indeed, it appears very probable that part of the difficulty in underwater

vision is a problem closely related to what is known as "instrument myopia",[13] discussed in some detail by Hennessy and Leibowitz. This refers to the unnecessary accommodation occurring when looking through an optical instrument. If it is the visibility of the rim of the eyepiece which is the cause, it is quite conceivable that the rim of the face-mask induces a similar response. Such over-accommodation could well interfere with acuity.

Until the problem may be corrected by new face-masks, it appears that in attempting to judge the relative distance of distant objects under water, the diver's precision will be improved if there are no nearby objects in his peripheral field of view.

REFERENCES

1. Ross, H. E., Stereoscopic acuity under water, Underwater Association Rep. 1966-67 (Lythgoe, J. N. and Woods, J. D., Eds.) 61-64
2. Luria, S. M., Stereoscopic acuity underwater, NSMC Rep. No. 510, Feb 1968
3. Whiteside, T. C. D., Vision at high altitude, Roy. Air Force Inst. Aviat. Med Flying Personnel Res. Comm. Rep. No. 910, Nov 1954.
4. Goldstein, J. H., Clahane, A. C. and Sanfilippo, S., The role of the periphery in binocular vision, Am. J. Ophthal., 62, 702-706, 1966.
5. Luria, S. M., Stereoscopic and resolution acuity with varying fields of view, NSMC Rep. No. 557, Dec 1968.
6. Whiteside, T. C. D. and Gronow, D. G. C., Vision in an empty visual field. The effect of empty field myopia upon the minimum visual angle, Roy. Air Force Inst. Aviat. Med. Flying Personnel Res. Comm. Rep. No. 872, Mar 1954.
7. Brown, R. H., "Empty-field" myopia and visibility of distant objects at high altitudes, Am. J. Psychol., 71, 376-385, 1958.
8. See, for example, Dwyer, W.O. and Lit, A., Effect of luminance-matched wavelength on depth discrimination at scotopic and photopic levels of target illumination, J. Opt. Soc. Am., 60, 127-131, 1970.
9. Luria, S. M. and Weissman, S., Relationship between dynamic and static stereoacuity, J. exp. Psychol., 76, 51-56, 1968.
10. Siegel, S., Nonparametric Statistics for the Behavioral Sciences, New York: McGraw-Hill Book Co., Inc., 1956 pp. 166-172.
11. Ref. 10, pp 75-83.
12. Hennessy, R. T. and Leibowitz, H. W., The effect of a peripheral stimulus on accommodation, Percept. and Psychophysics (in press).
13. Schober, H. A. W., Dehler, H. and Kassel, R., Accommodation during observations with optical instruments, J. Opt. Soc. Am., 60, 103-107, 1970.

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13. ABSTRACT

A variety of experiments were carried out in an attempt to improve stereoacuity under water by providing additional peripheral stimulation. Acuity is most improved when the peripheral stimuli are at the same distance from the observer as the target. As the peripheral stimuli are moved closer to the observer than the target, their beneficial effects are decreased and beyond a certain point their presence degrades acuity. This effect seems to be enhanced by increasing turbidity of the water, which decreases the contrast of the distant target relative to that of the nearby peripheral stimuli.

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